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EXPLOSIVE-ACTIVATED SAFE-ARM DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. provisional application serial number 60/424,988, filed November 8, 2002.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] This invention relates to an explosive-activated safe-arm device for conveying non-electric initiation signals.

[0003] Various kinds of devices are designed to function in response to a non-electric, e.g., explosive, initiation signal from an external initiation source. Often, the external initiation source comprises a signal transfer line that is connected to the device in a manner that permits the release of an explosive initiation signal from the signal line to the device. The signal line may comprise detonating cord, which inherently transmits an explosive output signal at all points along its length, but which is typically equipped with a coupling fixture to facilitate the connection of the signal line and the transfer of the explosive initiation signal to a target device. Alternatively, the signal line may comprise a signal tube, such as shock tube, having an end fixture coupled thereto, e.g., a detonator or pyrotechnic initiator, that is configured to generate a brisant output from the signal in the signal tube. For some devices it is necessary to include a delay member to interpose a time delay between the receipt of the explosive signal from the external initiation source and the transfer of the initiation signal to the explosively initiated device. Delay members typically comprise means for generating an explosive output signal at the end of the delay interval following the receipt of an initiation signal. The explosively initiated device or "target device" further comprises a direct-initiation fixture designed to receive the explosive output signal from the delay member and to function in response thereto, typically without delay.

[0004] Some delay members are liable to initiation apart from receipt of the external explosive initiation signal, and may then cause unintended functioning of the target device. Avoidance of such unintentional functioning is generally recognized as an important design goal, especially when there is a high cost associated with the functioning of the target device (e.g., target devices such as warheads and rocket motors).

Related Art

[0005] U.S. Patent 2,737,892 to Dalton et al, entitled "On-Off Self Destruction Base Fuze", dated March 13, 1956, discloses a fuze for the self destruction of a projectile that fails to function normally. The device is mounted within the explosive or propulsive charge in the projectile casing. The device includes a housing within which is disposed a delay powder train 31 with an associated output charge, detonator 29. The output charge must initiate a booster charge 32 via explosive pellets 42 and 43 in order to initiate self destruction of the projectile. The intervening pellets 42 and 43 are mounted on rotatable plates which, when the projectile rotates as a result of being fired, move in response to the rotation by aligning the pellets. Should the projectile still be rotating in flight by the time the delay train has been consumed, the output charge 29 will initiate the booster charge 32 by initiating, in sequence, the aligned intervening pellets 43 and 42. The plates 17 are eccentrically-mounted rotors which are moved by centrifugal force when the projectile is in flight.

[0006] U.S. Patent 4,328,754 to Goodman, dated May 11, 1982 and entitled "Time Delay Device", discloses a mechanism for the delayed release of a spring-driven firing pin. The operation of the release depends upon the movement of a release piston under the force of a spring. The action of the spring, however, is resisted by a reservoir of gas which must be dissipated through a narrow aperture to permit the piston to move. Thus, the gas controls the speed of the piston and thus determines a delay interval between the activation of the delay device and the release of the firing pin.

[0007] U.S. Patent 4,660,473 to Bender et al, dated April 28, 1987, entitled "Compressed Gas-Actuated Mechanical Power Element", discloses a housing containing a pair of movable pistons that can be extended from the housing under the force of compressed gas introduced into the housing.

[0008] U.S. Patent 4,932,325 to Hütter, dated June 12, 1990, entitled "Safety Device For An Aerodynamic Body Fuse", discloses a device for an aerodynamic body, in which functional parts are mounted on a slide that can be moved from a safe position within the contour of the body to an armed position beyond the contour of the body. The slide defines two air passages that face in opposite directions, so that when the slide is disposed in a moving air stream, a different air pressure is created in each perforation. The perforations communicate with a piston chamber and the difference in pressure is employed to move a piston from a safe position to an armed position.

[0009] U.S. Patent 3,938,443 to Wolski, dated February 17, 1976, entitled "Logic Module", discloses a mechanical logic module for a missile fuse device. The logic module makes use of the passage of air through a conduit to create a pressure differential to operate a piston. The piston rotates a cam which constitutes part of a safe-arm device.

[0010] A prior art safing mechanism employed on aerospace devices is illustrated schematically in Figure 4. In this device, an input fixture 116 and an output (receiving) fixture 114 are mounted for signal transfer from one to the other in a housing 112. The housing 112 defines a piston chamber 112b within which a barrier piston 124 resides. Barrier piston 124 includes a shield portion 124a that can be disposed between fixture 116 and 114 to prevent signal transfer from one to the other. Barrier piston 124 is initially in an "armed" position, in which shield portion 124a does not obstruct signal transfer from fixture 116 to fixture 114. Safing device 110 includes a cap 113 that is configured to receive a safing fixture 111. Each of fixtures 116, 114 and 111 comprises a threaded stainless steel ferrule that can be secured to housing 112 or cap 113, respectively, and which is secured to a signal transmission device (detonating cord) that terminates in an explosive-filled cup that protrudes through the ferrule into housing 112. In normal use, an input signal received on the signal line connected to input fixture 116 causes an initiation signal to be released into housing 112 to initiate a signal in the output fixture 114. However, should safing fixture 111 receive a safing signal, it will release gas into the top portion of chamber 112b that will impel barrier piston 124 downward (as sensed in Figure 4) so that the shield portion 124a will obstruct the transfer of a signal from fixture 116 to fixture 114. The signal that initiates safing fixture 111 may be generated in response to an external condition that would make the initiation of a signal in output fixture 114 undesirable.

SUMMARY OF THE INVENTION

[0011] This invention provides a safe-arm device comprising a housing defining at least one inlet aperture, an outlet aperture, and a barrier chamber. There is a barrier member in the barrier chamber that is movable therein from a safe position to an armed position in response to impelling gas introduced into the housing. There is also a delayed output component in the housing. The delayed output component is responsive to an input signal, for generating a delayed initiation signal. The barrier member, when in the safe position, is situated to inhibit initiation of an output device in the outlet aperture by the delayed output component and, when in the armed position, is situated to permit the delayed output component to initiate such output device.

[0012] According to one aspect of the invention, the barrier member, when in the safe position, may be situated between the delayed output component and the outlet aperture.

[0013] According to another aspect of the invention, the device may be configured to admit impelling gas from an input device in the inlet aperture into the barrier chamber to move the barrier member.

[0014] Optionally, the device may comprise an impelling gas source that is responsive to a signal from an input device. For example, the device may comprise a signal transfer device that comprises first and second signal transfer fixtures joined by a signal line. The first signal transfer fixture may be secured in the housing and configured for initiation by an input device in the inlet aperture and the second signal transfer fixture may comprise an arming fixture comprising the impelling gas source, and may be secured in the housing to release gas into the barrier chamber in response to a signal from the first signal transfer fixture. Alternatively, the first signal transfer fixture may comprise an arming fixture comprising the impelling gas source and may be secured in the housing to release gas into the barrier chamber in response to a signal from an input fixture, and the second signal transfer fixture may be secured in the housing and configured to initiate the delayed output component in response to a signal from the first signal transfer fixture.

[0015] According to various other aspects of the invention, the device may be combined with an input device secured in each inlet aperture for initiating the delayed output component and introducing impelling gas into the housing, and with an output device secured in the outlet aperture for initiation by the delayed output component. In such case, the housing is preferably sealed against the escape of impelling gas.

[0016] Optionally, there may be a single input device for both introducing impelling gas into the housing and initiating the delayed output component. Alternatively, one input device may introduce the impelling gas and another may initiate the delayed output component.

[0017] The barrier chamber may comprise a piston chamber portion and an output initiation portion. The barrier member may comprise a piston segment in the piston chamber portion, and a middle segment and a shield segment in the output initiation portion of the barrier chamber, wherein the middle segment of the barrier member is configured to substantially isolate the outlet aperture from impelling gas introduced into the piston chamber portion.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] Figure 1 is a schematic cross-sectional view of a safe-arm device according to a first embodiment of the invention;

[0019] Figure 2A is a schematic cross-sectional view of a safe-arm device according to a second embodiment of the invention;

[0020] Figure 2B is a view of a device similar to Figure 2A except that it comprises two input devices, one of which is a gas-generating fixture which is independent of, i.e., not responsive to, the other input fixture;

[0021] Figure 3A is a schematic cross-sectional view of a safe-arm device according to a third embodiment of the invention;

[0022] Figure 3B is a schematic cross-sectional view of a portion of the barrier member in a portion of the barrier chamber of the device of Figure 3A; and

[0023] Figure 4 is a schematic cross-sectional view of a prior art safing device.

DETAILED DESCRIPTION OF THE INVENTION AND PREFERRED EMBODIMENTS THEREOF

[0024] The safe-arm device of this invention finds utility in various fields, including aerospace and military applications, for reliably transferring a non-electric initiation signal through a housing from an input device to an output device. The safe-arm device includes a delayed output component which generates an initiation signal for an output device coupled to the housing after a delay interval following the receipt of a signal from the input device (the input signal). To prevent the delayed output component from inadvertently initiating the output device in the absence of an input signal from an input device, there is a movable barrier member in the housing that is initially positioned to inhibit the transfer of a delayed initiation signal from the delayed output component to an output device, i.e., it is initially in a "safe" position between the delayed output component and the output device. However, the barrier member is movable to a non-inhibiting position, i.e., to an "armed" position, in which it permits the delayed output component to initiate the output device. The delayed output component may function solely to postpone the initiation of the output device for an interval sufficient to permit movement of the barrier member, or it may serve additional functions (such as the initiation of other devices) during the delay interval as well.

[0025] The safe-arm device may include a retainer (e.g., a shear pin) for releasably retaining the barrier in the safe position until the receipt of the input signal, and may also include a locking mechanism (e.g., locking tabs and grooves) to keep the barrier in the armed position thereafter.

[0026] Preferably, the barrier member is movable in response to the introduction of impelling gas into the housing when the input signal is received. In such embodiments, the housing

defines a barrier chamber in which a piston portion of the barrier member resides. A pressure difference from one side of the piston portion to the other will cause the barrier member to move. To assure that the impelling gas, which may be highly energetic (i.e., hot and highly pressurized), moves the barrier member but does not initiate the output device, the housing and barrier member are configured so that the output device is substantially isolated from the impelling gas.

[0027] Should the delayed output component function inadvertently, i.e., without the receipt of an input signal to generate impelling gas, the barrier member will prevent the delayed output component from initiating the output device by blocking the debris, heat and shock of the delayed initiation signal from the output device. Gas produced by the delayed output component may also move the barrier from the safe position, but such movement would occur after the delayed initiation signal has been blocked from the output device.

[0028] In some embodiments of this invention, the impelling gas is obtained at least in part from an input device that has been secured to the housing. In such embodiment, the input device comprises a gas-generating fixture which introduces impelling gas into the housing, and the housing is configured so that the impelling gas can flow into an impelling region in the barrier chamber from the input device. In other embodiments, the safe-arm device of this invention comprises a gas-generating fixture that is distinct from, but responsive to, the input device, and the input device need not contribute impelling gas. In still other embodiments, the impelling gas is provided by the input device together with gas from a gas-generating fixture responsive to it. Optionally, there may be an intervening signal transfer device to convey an initiation signal from an input device to the delayed output component, or from the input device to a gas-generating fixture for the generation of impelling gas. According to still other embodiments, the distinct gas-generating fixture may constitute an input device that is distinct from the input device that initiates the delayed output component.

[0029] Preferably, all devices mounted in the housing, e.g., the at least one input device, output device and the optional signal transfer device and gas-generating fixture, etc., form a seal with the housing so that the impelling gas is not subject to loss in pressure due to leakage from the housing, and to prevent the introduction of gas into the housing from the environment. By sealing the safe-arm device against gas leaks, the maximum efficacy of impelling gas introduced into the device will be obtained and the need for an external power source for moving the barrier member can be avoided, i.e., the device can be self-contained.

[0030] One embodiment of an explosive safe-arm device in accordance with this invention is seen in Figure 1 together with an input device 16 and an output device 14. Safe-arm device

10 comprises a housing 12 which includes a fixture seat 13a. Fixture seat 13a defines an inlet aperture 13b which includes an expansion chamber 13a. Housing 12 encloses a delayed output component 17 in a component chamber 12a. There is a barrier chamber 12b in housing 12 and a barrier member 24 movably disposed therein, and an outlet aperture 12g. An input device 16 is secured in inlet aperture 13b and an output device 14 is secured in outlet aperture 12g and housing 12 is otherwise sealed such that gas cannot enter or escape housing 12. The input device 16 is capable of emitting a signal that can initiate the delayed output component 17. It also introduces impelling gas into the housing to move the barrier member 24, as described below.

[0031] In the illustrated embodiment, input device 16 comprises an input fixture 16a secured to a signal line 18 such as detonating cord. Input device 16 may optionally comprise an FCDCA (flexible confined detonating cord assembly), a type of signal-transfer apparatus well known in the art. When initiated, the end tip of an FCDCA generates a brisant output signal and a flyer plate derived from the cup. (An FCDCA can also be used to receive a signal and transfer the signal to the detonating cord thereof, as occurs with the output device 14. Accordingly, the end fixture of an FCDCA is referred to herein generically as a signal transfer fixture.) Accordingly, input fixture 16a is a signal transfer fixture comprising a longitudinal bore therethrough where a signal transfer line comprising a flexible, confined detonating cord (e.g., a length of 2.7 grains per foot HNS-IIA Aluminum Mild detonating fuse, surrounded by flexible shielding (which my included braided stainless steel with moisture barrier therein)) is received. An end tip 16b comprising a transfer charge of reactive (i.e., pyrotechnic or explosive) material such as HNS disposed in a cup is secured on the end of the signal transfer line and protrudes from the fixture 16a. Input fixture 16a is configured so that it can easily be secured to the housing (e.g., it may have screw threads that mate with threads in the housing) with end tip 16b in position for signal transfer with another device (e.g., for initiation of a delay device or signal transfer device).

[0032] Delayed output component 17 includes a delay member 20 and a ferrule 26 which carries a percussion cap 28. Delay member 20 comprises a sleeve 20b filled with a pyrotechnic delay material 20d. Sleeve 20b carries an annular flange 20a disposed concentrically about delay member 20. The input end of sleeve 20b is disposed within ferrule 26, which is secured to flange 20a. Ferrule 26 defines an expansion chamber around delay member 20 to permit the expansion of gas generated by delay material 20d. Ferrule 26 carries percussion cap 28 at a position where the cap 28 can be initiated by an input device secured in the inlet aperture of the housing, and where, upon initiation, cap 28 will initiate the delay material 20d from across a short spacing gap. A seal 27 on the end of ferrule 26 covers over percussion cap 28 to protect

the cap against desensitization by environmental factors, e.g., moisture. Seal 27 is sufficiently thin and input device 16 is sufficiently powerful that seal 27 does not prevent input device 16 from initiating cap 28. Ferrule 26 is configured so that it leaves an annular gas-flow passage about its exterior, between itself and the interior surface of component chamber 12a, for reasons discussed below.

[0033] The output end of sleeve 20b carries a delayed initiation charge 22 which contains a charge of reactive material, e.g., an explosive material such as HNS, in a cup and which is sensitive to initiation by pyrotechnic delay material 20d. As shown, delayed initiation charge 22 has access to barrier chamber 12b from component chamber 12a via an initiation aperture (unnumbered) in the housing. When initiated, delayed initiation charge 22 releases a delayed initiation signal that may include a flyer and that is sufficiently energetic to initiate an output device.

[0034] Housing 12 defines a barrier chamber 12b within which barrier member 24 resides. One portion of barrier chamber 12b, which is closed by barrier plug 12c, is referred to herein as a piston chamber 12d, and another portion of barrier chamber 12b is an output transfer portion 12e. A piston segment 24b of barrier member 24 is configured to closely match the walls of piston chamber 12d and a middle segment 24c of barrier member 24 is configured for a substantially sealing fit within output transfer portion 12e. Barrier chamber 12b and barrier member 24 are configured to prevent barrier member 24 from rotating within chamber 12b, e.g., they may comprise a groove and slot engagement between them.

[0035] High-pressure impelling gas can be introduced into piston chamber 12d at a point below piston segment 24b (as sensed in Figure 1) (referred to herein as the impelling region 12h), where the impelling gas is blocked from direct entry into output transfer portion 12e by middle segment 24c of barrier member 24. The high pressure in the impelling region 12h will cause barrier member 24 to move as indicated by the upward-pointing arrow in Figure 1.

[0036] A longitudinal pressure relief aperture 24e extends from the top of the piston segment 24b of barrier member 24 to the bottom of the shield segment 24d. At least some of the non-impelling gas in the upper portion of barrier chamber 12b (as sensed in Figure 1) that would otherwise be compressed by the motion of barrier member 24 to its armed position may therefore be displaced into the output transfer portion 12e of barrier chamber 12b. Thus, resistance against the movement of barrier member 24 to the armed position due to the compression of non-impelling gas in the housing is significantly reduced. Nevertheless, middle segment 24c of barrier member 24 substantially establishes a seal with barrier chamber 12b to prevent the entry of impelling gas from the piston chamber 12d into output transfer portion 12e. Thus, bar-

rier member 24 is configured to isolate the outlet aperture, and an output device mounted therein, from impelling gas. The seals established by piston segment 24b and middle segment 24c may be facilitated by the use of ring seals, as shown in device 10", Figure 3A.

[0037] Delayed initiation charge 22 of delayed output component 17 is positioned so that when initiated, it releases a signal, optionally including a flyer, into output transfer portion 12e, for initiating an output device. Barrier member 24 includes a shield segment 24d extending from middle segment 24c. Shield segment 24d is configured to be interposed between the delayed initiation charge 22 and an output device when barrier member 24 is in the safe position. Optionally, the shield segment 24d may be designed to simulate a fixed, simply-supported beam, rather than a fixed-free beam.

[0038] Optionally, barrier member 24 may be held in the safe position by retaining means such as a shear pin in a double-shear configuration (not shown), designed to prevent barrier 24 from moving in chamber 12b in response to non-initiating stimuli, such as vibrations, but which permits the barrier to move to the armed position under the influence of impelling gas.

[0039] As indicated above, the delayed initiation charge 22 is positioned for initiation of an output device disposed in the output transfer portion 12e of the housing. Typically, an output device comprises an output initiating charge mounted within output transfer portion 12e at the outlet aperture of the housing, so the delayed initiation charge 22 is preferably positioned close to the outlet aperture 12g. In the illustrated embodiment, output device 14 comprises an FCDCA, just as does input device 16, and the end tip thereof (which contains the HNS initiation transfer charge) protrudes into output transfer portion 12e of barrier chamber 12b from the outlet aperture 12g of the housing. There is a gap between the output device 14 and the delayed initiation charge 22 within which the shield segment 24d of barrier member 24 can reside when it is in the safe position. Absent the intervening shield segment 24d, the delayed initiation signal from delayed initiation charge 22 can initiate the output device 14, which initiates the attached signal line 15, which in turn can then initiate the principal functioning charge of the target device, e.g., a warhead, rocket motor, etc. When in the safe position, the shield segment 24d is physically disposed between delayed initiation charge 22 and output device 14, and so shields the output device 14 from the debris, heat and shock of the signal generated by delayed initiation charge 22, thus preventing the initiation of a signal in output device 14.

[0040] To move barrier member 24 from the safe position to the armed position, impelling gas is introduced into the barrier chamber 12b to create a pressure difference from one side of piston segment 24b to the other, with the greater pressure being in the impelling region 12h below piston segment 24b (as sensed in Figure 1). Optionally, as in the embodiment of Figure

1, the impelling gas may be obtained from input device 16, i.e., from the function of the end tip thereof. Accordingly, fixture seat 13 is preferably configured to avoid forming a seal with delayed output component 17 (which would prevent gas flow beyond inlet aperture 13b). In addition, ferrule 26 is configured to leave a gas flow opening between its exterior surface and the interior surface of component chamber 12a and a conduit 30 is provided to accommodate the flow of gas from component chamber 12a to the impelling region 12h of piston chamber 12d. (Conduit 30 may be provided by drilling a hole through housing 12, through component chamber 12a to barrier chamber 12b and then plugging the hole with a plug 32.) A seal 20c, e.g., a ring seal or o-ring bushing, between ferrule 26 and the interior surface of component chamber 12a prevents impelling gas from entering output transfer portion 12e via the initiation aperture by which delayed initiation charge 22 has access to barrier chamber 12b. Seal 20c is positioned so that it does not impede the flow of impelling gas from input device 16 into conduit 30, i.e., it is between the initiation aperture and the opening of conduit 30 to the component chamber 12a.

[0041] The movement of barrier member 24 is responsive to the flow of high pressure impelling gases generated by input device 16 into impelling region 12a of barrier chamber 12b via conduit 30. The pressure beneath piston segment 24b impels barrier member 24 upward (as sensed in Figure 1), to the "armed" position, in which the shield segment 24d of barrier member 24 is no longer disposed between delayed initiation charge 22 and output device 14, so the delayed initiation signal from delayed initiation charge 22 can initiate output device 14. If the safe-arm device 10 comprises a retainer for holding barrier member 24 in the safe position, the retainer is designed so that it yields to the force imposed by the impelling gas. For example, if the retainer comprises a shear pin, the shear pin is designed to shear under the force produced by the impelling gas. This occurs within a shorter time interval than the delay interval provided by delayed output component 17 between its initiation by input device 16 and the initiation of charge 22. In a particular embodiment, the impelling gas moves the barrier member from the safe position to the armed position within about 1 millisecond, whereas the delayed output component provides a delay of about 350 milliseconds. Cap 12c is configured to withstand the impact of barrier member 24 when it moves to the armed position. In some embodiments, the pressure of the gases in barrier chamber 12b may keep barrier member 24 in the armed position for long enough to permit the initiation of the output device. Preferably, to assure that barrier member 24 remains in the armed position, a locking mechanism may be incorporated into safe-arm device 10. The illustrated embodiment comprises locking means that include a spring-loaded locking pin 34 that bears on barrier member 24, which includes a pin recess 24a. When

barrier member 24 reaches its armed position, pin 34 is received within pin recess 24a, thus preventing barrier member 24 from returning to the safe position.

[0042] In the illustrated embodiment, the housing 12 is sealed by input device 16, output device 14, cap 12c and plug 32 against the escape of gas from the housing. This helps assure that the impelling gas generates and maintains sufficient pressure to move barrier member 24 from the safe position to the armed position.

[0043] In operation, safe-arm device 10 is initially configured as shown in Figure 1, with barrier member 24 in the safe position. Upon receipt of an initiation signal from the external initiation signal line 18, input device 16 emits an explosive signal which includes high pressure gases and a flyer plate (not shown). The flyer plate traverses expansion chamber 13a and strikes percussion cap 28 which, in turn, initiates the delay composition in delay member 20. Meanwhile, the expanding gases of input device 16 flow from inlet aperture 13b through conduit 30 to the impelling region 12h of barrier chamber 12b to move barrier member 24 from the safe position to the armed position as indicated by the arrow (unnumbered). The delay member 20, after the pyrotechnic material 20d is consumed, releases an explosive delayed initiation signal from delayed initiation charge 22 which initiates output device 14. Thus, input device 16 directly initiates delayed output component 17 and also directly provides impelling gas to the barrier chamber 12b.

[0044] Pyrotechnic delay members such as delay member 20 are well-known in the art. In alternative embodiments, the delayed output component 17 may comprise an electronic delay unit instead of a pyrotechnic delay member. An electronic delay unit that may be used with a non-electric input device may comprise a transducer for converting the non-electric input signal to an electrical signal, storage means for storing the converted input signal, an electrically initiated delayed initiation charge 22 and a timer-controlled switching circuit for releasing the stored input signal to the delayed initiation charge 22 after the desired interval. Electronic delay units of this kind are well-known in the art, as seen, e.g., in U.S. Patents 5,377,592 and 6,079,332, both of which are hereby incorporated herein by reference as background information.

[0045] As mentioned above, it is not necessary that the impelling gas come directly from an input device. Optionally, impelling gas can be provided by an impelling gas source that is part of the safe-arm device itself and distinct from, but is responsive to, the input device, so the input device indirectly introduces the impelling gas into the housing. For example, in the embodiment of Figure 2A, safe-arm device 10' comprises a housing 12' within which direct initiation output device 14 and a delayed output component 17 are disposed. Housing 12' defines a

barrier chamber 12b where barrier member 24' is situated. Barrier member 24' is movable between a safe position and an armed position to prevent or permit signal transfer from the delayed output component 17 to an output device 14 following receipt of an input signal from an input device 16. All of these structures function in substantially the same way as their corresponding structures in safe-arm device 10 (Figure 1), except as indicated by the following description.

[0046] Device 10' comprises a signal transfer device 35 such as an FCDCA having a signal transfer fixture on each end of the signal line. (Alternatively, the signal transfer device 35 may comprise any other kind of signal line such as shock tube, low velocity signal tube, etc., with suitable signal transfer fixtures (e.g., initiation caps or squibs) at opposite ends thereof.) The signal transfer device 35 comprises an arming fixture 36 that is secured in housing 12' and which comprises an end tip configured and positioned to release the energized impelling gas into the impelling region 12h of barrier chamber 12b. Arming fixture 36 functions in response to a signal received via signal transfer line 40 from input signal transfer fixture 38, which is secured in housing 12 for initiation by input device 16. Transfer fixture 38 transfers an initiation signal to arming fixture 36 within a time interval that is shorter than the delay interval provided by delay member 20. Since safe-arm device 10' thus comprises its own source of impelling gas (arming fixture 36), the input device need not be one that generates such gas. Further, since arming fixture 36 introduces impelling gas directly into the piston chamber, it is not necessary for housing 12' to have a channel such as conduit 30 (Figure 1) to provide gas flow communication from input device 16 to barrier chamber 12b.

[0047] In use, an initiation signal received via signal line 18 causes input device 16 to release an explosive initiation signal into housing 12', which initiates transfer fixture 38 and percussion cap 28. Transfer fixture 38 generates an initiation signal that is transferred via transfer line 40 to arming fixture 36. The gases released from arming fixture 36 cause barrier member 24' to move to the armed position. Meanwhile, percussion cap 28 initiates delay member 20. After passage of a delay interval imposed by the controlled burning of pyrotechnic delay material 20d, by which time barrier member 24' has moved to the armed position, delay member 20 generates an initiation signal from delayed initiation charge 22. With barrier member 24' in the armed position, the output signal from delayed initiation charge 22 can initiate output device 14. Thus, input fixture 16 has introduced impelling gas into housing 12' (albeit indirectly), and also initiated the delayed output component 17.

[0048] Another embodiment of this invention is shown as device 10a' in Figure 2B. Device 10a' is generally similar in construction and function to device 10', and corresponding structures

there are labeled with corresponding reference numerals. Accordingly, the description of device 10' of Figure 2A will convey an understanding of device 10a' with the following additional explanation.

[0049] Safe-arm device 10a', like safe-arm device 10' of Figure 2A, makes use of an input device that is situated to initiate the delayed output component upon receipt of an input signal from line 18a, and is isolated (for purposes of providing impelling gas) from barrier chamber 12b. Safe-arm device 10a' also comprises a gas-generating input device 36a which is configured and situated in an inlet aperture to barrier chamber 12b to release impelling gas into barrier chamber 12b upon receipt of an input signal on line 18b. However, unlike fixture 36 of device 10' (Figure 2A), the gas-generating input device 36a is not responsive to the output from input device 16. Instead, input device 36a receives an initiating signal from line 18b, which may obtain its input signal from a different source from the signal source for line 18a, and the function of the different sources may be subject to different safety conditions from each other. Thus, the introduction of impelling gas into the housing is independent of the initiation of the delayed output component.

[0050] In yet another embodiment of this invention, safe-arm device 10" shown in Figure 3A comprises a housing 12" that defines an inlet aperture 13b that is connected via gas flow conduit 30' to impelling region 12h of barrier chamber 12b. Housing 12" also defines a first transfer aperture 13c in which a signal transfer device can be secured for communication with input device 16. Housing 12" contains a barrier member 24' which is movably disposed within barrier chamber 12b. Barrier chamber 12b and barrier member 24' are similar to the corresponding barrier member 24 and barrier chamber 12b of the embodiments of Figures 1 and 2, except that barrier member 24" does not have a pressure relief aperture, such as aperture 24e of piston 24 (Figure 2A), which is unnecessary in safe-arm device 10", for reasons discussed below. Barrier member 24' is equipped with ring seal 24k in piston segment 24b' and ring seals 24m in middle segment 24c' to facilitate the achievement of the seals described above.

[0051] In safe-arm device 10", the delayed output component is isolated from input device 16 by housing 12". Accordingly, signal transfer device 37 is provided to transfer an initiation signal from input device 16 to the delayed output component 17. Transfer device 37 comprises a transfer fixture 38 that is positioned for initiation by input fixture 16, and to convey the signal to a signal line 18 and, in turn, to fixture 36. Fixture 36 is similar in configuration to input fixture 16 of Figure 1 or Figure 2A, and is configured and situated to be able to initiate the delayed output component 17.

[0052] Delayed output component 17 of safe-arm device 10" has the same as configuration and function as delayed output component 17 of device 10' (Figure 2A).

[0053] Safe-arm device 10" is generally similar to safe-arm device 10' (Figure 2A) with the following exceptions. First, a gas flow conduit 30' permits gas flow from two fixtures, input fixture 16 and transfer fixture 38, to the impelling region 12h of barrier chamber 12b', thus approximately doubling the pressure of the impelling gas that drives barrier member 24' relative to devices 10 and 10'. Accordingly, transfer fixture 38 constitutes a gas-generating fixture of device 10". In addition, inlet aperture 13b is isolated from delayed output component 17, so impelling gas will not be introduced into output region 12e via the initiation aperture by which delayed output component 17 is open to barrier chamber 12b. Further, the increased pressure of the impelling gas in impelling region 12h relative to devices 10 and 10' makes it unnecessary to provide barrier member 24' with a pressure relief aperture such as aperture 24e (Figure 1), since the impelling gas will have sufficient pressure to move barrier member 24' to an armed position despite the compression of gases in the upper portion of barrier chamber 12b'.

[0054] Furthermore, device 10" comprises a shear pin to provide a retainer to keep barrier member 24' in the safe position until an input signal is received. Also, barrier member 24' comprises tabs 24f (Figure 3B) on an upward-extending blade 24g on piston segment 24b. Tabs 24f are configured to engage vertical slots (not shown) in barrier chamber 12b to prevent barrier member 24' from rotating as it moves to its armed position. Barrier chamber 12b defines flared shoulders 12f adjacent cap 12c, and tabs 24f are deformable so that when impelling gas causes barrier member 24' to strike cap 12c, tabs 24f are deformed by the contact with cap 12c and engage shoulders 12f, thus preventing barrier member 24' from reversing direction and moving downward, towards the safe position. When barrier member 24' is in the armed position, delayed output component 17 initiates output fixture 14 as previously described for devices 10 and 10'.

[0055] Although the invention has been described with reference to particular embodiments thereof, it will be understood by one of ordinary skill in the art, upon a reading of the foregoing disclosure, that various alterations to the described embodiments fall within the scope and spirit of the invention.